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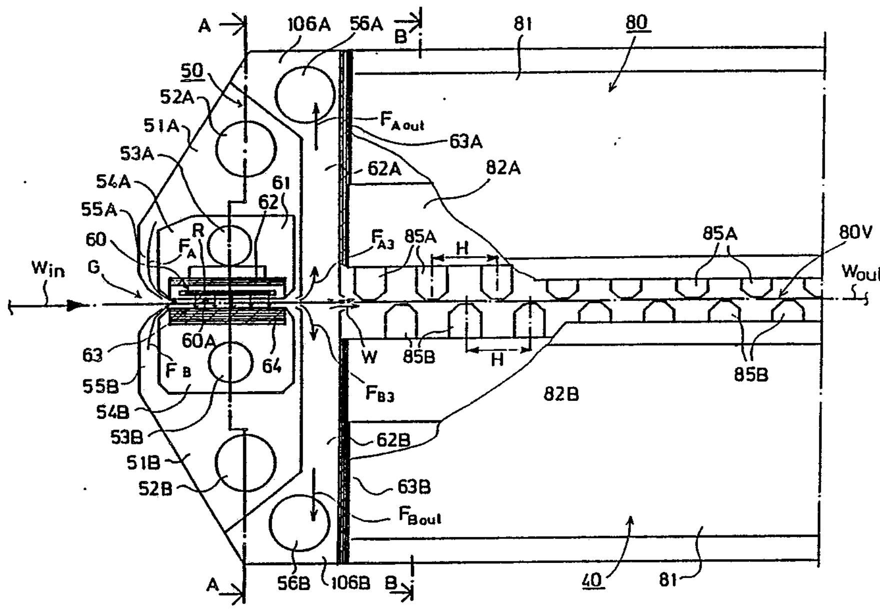

(57) Abstract

Method and device for contact-free drying of a paper or board web (W) or of any other, corresponding continuous web (W). In the drying, both infrared radiation (R) and drying air jets are used, by means of which said air jets the web (W) running through the dryer (40) is, at the same time, carried free of contact. The moving web (W) is first passed into an infrared drying gap, in which a drying energy pulse of relatively short duration is directed at the web (W), the power of the said energy pulse being substantially higher than the average drying power of the dryer per unit of area. After the infrared drying gap, the web (W) is immediately passeed into an airborne web-drying gap (80V), wherein the web (W) is supported and dried by means of air jets. Air (F_{Ain}, F_{Bin}) is brought into the infrared unit (50), which said air, having been heated in the infrared unit (50), is passed as replacement air and/or drying air for the airborne web-drying unit (80, 90) or units (80, 90) placed after the infrared unit. The airflows (F_{Ain}, F_{Bin}) to be passed into the infrared unit (F) are passed in connection with the inlet gap (G) of the web (W) to both sides of the web (W) so as to make accompanying and sealing jets (F_A, F_B).

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Method and device in on-machine coating-drying of a paper web or equivalent

The invention concerns a method for contact-free drying of a paper or board web or of any other, corresponding continuous web, in which method both infrared radiation and drying air jets are used for drying, by means of which said air jets the web running through the dryer is, at the same time, carried free of contact, preferably from two sides, and in which method, after the infrared drying gap, the web is substantially immediately passed into an airborne web-drying gap, wherein the web is supported and dried by means of air jets.

The invention further concerns a device intended for carrying out the method of the invention, which said device comprises an infrared drying unit and an airborne web-drying unit or airborne web-drying units, which said infrared drying unit comprises a series of infrared radiators and an infrared treatment gap fitted in its connection, through which said gap the web to be dried can be passed, and which said airborne web-drying unit or units comprise a box portion, inside of which a nozzle box or boxes are fitted, in connection with which there are nozzle parts, through which drying and supporting air jets are applied to the web to be dried, which said device comprises an infrared drying unit and an airborne web-drying unit, which are integrated with each other both structurally and functionally, and which said infrared unit is placed, in the direction of running of the web to be dried, immediately before the airborne web-drying unit.

The present invention relates to the drying of a paper web, board web, or of any other, corresponding moving web. A typical object of application of the invention is the drying of a paper web in connection with its coating or surface-sizing.

As is known in prior art, paper webs are coated either by means of separate coating devices or by means of on-machine devices or surface-sizing devices integrated in paper machines and operating in the drying section of a paper machine so that, at the final end of a multi-cylinder dryer, the web to be coated is passed to a coating device, which is followed by an intermediate dryer and finally, e.g., by one group of drying cylinders as an after-dryer. A typical object of application of the present invention is exactly the said intermediate dryer after the coating device, the invention being, however, not confined to said intermediate dryer alone.

In prior art, so-called airborne web dryers are known, wherein a paper web, board web, or equivalent is dried free of contact. Airborne web dryers are used, e.g., in paper coating devices after a roll coater or a spread coater to support and to dry the web, which is wet with the coating agent, free of contact. In airborne web dryers various blow nozzles and nozzle settings for drying and supporting air are applied. The said blow nozzles can be divided into two groups, i.e. pressure or float nozzles, and negative-pressure or foil nozzles, both of which can be applied in the dryer and the method in accordance with the invention.

The prior-art airborne web dryers that are used most commonly are based exclusively on air blows. It is partly for this reason that the airborne web dryer becomes quite spacious, because the distance of effect of the airborne web dryer must be relatively long in order that a sufficiently high drying capacity could be obtained. Another reason for these drawbacks is that in air drying the depth of penetration of the drying remains relatively low.

In prior art, different dryers are known which are based on the effect of radiation, in particular of infrared radiation. The use of infrared radiation provides the advantage that the radiation has a relatively

high depth of penetration, which depth of penetration is increased when the wavelength becomes shorter. The use of infrared dryers in the drying of paper web has been hampered, e.g., by the risk of fire, because the temperatures in infrared radiators become quite high, e.g. 2000°C, in order that a drying radiation with a sufficiently short wavelength could be achieved.

In respect of the prior art, reference is made to the German published Patent Application (DE OS) No. 2,351,280, which describes a sort of a combination of an airborne web dryer and an infrared dryer operating by means of pressure nozzles. In the patent application mentioned above, a one-sided airborne web dryer is described, which comprises nozzle boxes placed one after the other at distances from each other. The edge portions of these boxes are provided with nozzle slots, through which air jets are directed at the web placed above expressly perpendicularly, which said air jets are deflected outwards from the nozzle box when they meet the web. Between the said nozzles, infrared radiators are fitted, which fill the gap between the nozzles. As far as is known to the applicant of the present patent application, the said dryer has not become widely used, which is probably due to the fact that the nozzle construction has not been successful in providing a constructionally or energy-economically favourable combination of air drying and radiation drying. Moreover, the construction is one-sided, and it requires a relatively abundant space in the direction of running of the web if sufficiently high drying capacities are to be reached, e.g., in paper finishing plants.

Particular problems in infrared drying have been strong formation of dust and high humidity of air.

Electric infrared dryers as separate or as exclusively used are also energy-economically unfavourable owing to the relatively high cost of electric energy, as compared, e.g., with natural gas.

In paper coating stations, including on-machine coating stations, separate infrared dryers have been used whose drying is based exclusively on the radiation effect. However, by means of these infrared dryers, a sufficiently good adjustability of paper quality and evaporation has not been obtained. Moreover, the drying process becomes highly dependent on the operation quality of the infrared dryer.

The object of the present invention is to solve the problems described above.

It is a particular object of the present invention to develop a novel application of an infrared dryer, in which in particular the air technique has been solved in a better way than in prior art.

A further object of the invention is to provide a method and a device by means of which the overall control of the coating-drying of a paper web can be improved.

A partial objective of the invention is also to provide a novel application of an infrared dryer so that it is possible to accomplish a dryer concept of more favourable investment costs and operating costs, as compared with prior art. In view of achieving this objective, by means of the invention attempts are made to obtain a higher drying capacity, a lower size of equipment, and a lower heat and humidity load in the machine hall.

It is a particular object of the invention to provide such an application of an infrared dryer as can be used for adjusting the ultimate moisture profile of the web produced by the paper machine.

In view of achieving the objectives given above and those that will come out later, the method of the invention is mainly characterized in

- that in the method the moving web is first passed into an infrared drying gap, in which a drying energy pulse of relatively short duration is directed at the

web, the power of the said energy pulse being substantially higher than the average drying power of the dryer per unit of area, and

- that air is brought into the infrared unit, which said air, having been heated in the infrared unit, is passed as replacement air and/or drying air for the airborne web-drying unit or units placed after the infrared unit.

On the other hand, the drying device in accordance with the invention is mainly characterized in that the infrared drying unit comprises air and nozzle devices, through which air flows can be passed into the treatment gap of the infrared unit and/or into connection with the heated parts of the infrared unit, which said air flows are passed for replacement and/or drying air for the subsequent airborne web-drying unit or units.

By means of the invention, it is possible to accomplish a drying concept of improved overall profitability, wherein both the investment costs and the operating costs are taken into account.

Owing to the invention, an increased evaporation capacity, a reduced heat and humidity load in the machine hall, as well as economies in the lifting and auxiliary equipment for the infrared dryer are obtained. On the basis of measurements, drying test runs, and theoretical examinations carried out by the applicant, it has been ascertained that the solution of the invention is both evaporation-technically and in view of the quality of the paper web considerably better than the prior-art dryer arrangement in which the infrared dryer and the airborne web dryer are provided as separate independently operating units.

The method and device in accordance with the invention are particularly well suitable for an on-machine dryer after a coating or surface-sizing apparatus and, moreover, if necessary, also for adjustment of the ultimate moisture profile of the paper web.

In the present invention, an open hood does not have to be constructed above the dryer, which is the case in the prior-art devices, for in the infra-airborne combination of the invention a mere spot exhaustion is enough, because the system of exhaust ducts in the airborne web dryer takes care of adequate ventilation.

When natural gas or a corresponding fuel is used for the heating of the drying air for the airborne web dryer unit or units, the operating cost of the method and the device making use of the invention per unit of quantity of evaporated water becomes considerably more favourable as compared with a dryer in which electric infra drying alone would be used. This advantage is based thereon that in the invention the energy transferred into the paper web in the electric infrared unit is utilized efficiently in the airborne web drying unit or units following after the infrared unit.

In the following, the invention will be described in detail with reference to the prior art constituting the starting point of the present invention, illustrated in the figures in the accompanying drawings, as well as to some preferred embodiments of the invention.

Figure A shows the layout of an on-machine coating-dryer of a prior-art paper machine.

Figure 1 shows, in a way corresponding to Fig. A, the layout of a drying method and dryer in accordance with the present invention.

Figure 2 is a side view of an infra-airborne web-drying unit in accordance with the invention.

Figure 2A shows a section A-A in Fig. 2.

Figure 2B shows a section B-B in Fig. 2.

Figure 2C shows a two-sidedly blowing pressure nozzle unit applied in an airborne web dryer in accordance with the invention.

Figure 2D shows an alternative for the nozzle shown in Fig. 2C, i.e. a one-sidedly blowing coanda nozzle unit with negative pressure.

Figure 3 illustrates the method of the invention as an air-flow diagram.

Figure 4A shows the evaporating capacity of a prior-art dryer that comprises two separate infrared units as a function of time.

Figure 4B shows, in a way corresponding to Fig. 4A, the evaporating capacity of the infra-airborne dryer in accordance with the invention and shown in Fig. 1 as a function of time.

Fig. A shows a prior-art paper finishing and coating station placed in the drying section of a paper machine, wherein a prior-art drying arrangement is used. As is shown in Fig. A, the paper web W is passed over the cylinders 13 of a normal multi-cylinder dryer 10 placed inside a hood 12. The upper drying wire in the drying section 10 is denoted with reference numeral 11. The multi-cylinder dryer 10 is followed by measurement beams 13A placed across the web W, in connection with which said beams 13A there are measurement detectors in themselves known, such as detectors for the measurement of the web moisture and grammage. The measurement beams 13 are followed by an intermediate press formed by the rolls 14A and 14B, whereinafter the web W is passed, being guided by the guide rolls 15, into a coating station 20A in itself known. The coating station 20A comprises a coating unit and, after it, an infrared dryer 25 and a separate airborne web dryer 26.

The vertical beams in the frame of the coating station 20A are denoted with reference numeral 21a, and the horizontal beams with reference numeral 21b. After the coating unit 22, the web W is transferred, being guided by a guide roll 23, into the treatment gap 25V of a separate infrared dryer 25. The web W dried in the said treatment gap 25V is passed as remarkably long draws over the cylinder 23A into the treatment gap 26V of an airborne web dryer 26, wherein the web W is supported free of contact and wherein it is, at the same

time, dried by means of air jets discharged out of the nozzles (not shown) of the airborne web dryer 26.

After the airborne web dryer 26, the web W is transferred, guided by the guide rolls 27, to an after-dryer 30, whose first cylinder 33a is not provided with a felt. The after-dryer 30 is placed inside a hood 32, and its upper felt, which is guided by guide rolls 34, is denoted with reference numeral 31. The after-dryer 30 has, for example, only one cylinder group, which comprises, for example, four drying cylinders 33a and 33. After the after-dryer 30, the fully dried and coated web W is passed to the reeling device (not shown).

Above, in connection with Fig. A, a prior-art coating station 20A is described in considerable detail. Later, the operation and the capacity of the method and the device in accordance with the present invention will be compared exactly with the drying method and device in accordance with Fig. A.

Fig. 1 shows the same coating and drying process as in Fig. A, however, so that the coating station 20A shown in Fig. A has been substituted for by a coating station 20 in accordance with the present invention. It can be imagined that the coating station shown in Fig. A has been modernized by providing its coating station 20 with a novel dryer 40 in accordance with the invention, which is placed in connection with the frame part 21a and 21b of the earlier coating station 20A. In this modernization the multi-cylinder dryer 10 and the after-dryer 30 have remained unchanged. However, it should be emphasized that the dryer 40 in accordance with the invention is also suitable for many other applications, besides the application and position shown in Fig. 1.

The coating station 20 shown in Fig. 1 consists of a prior-art coating station 22 and an infrared-airborne web dryer 40 in accordance with the invention and of a separate conventional airborne web dryer 90 placed after same. The web W runs upwards vertically

through the treatment gap 40V of the infrared-airborne web dryer 40 and thereupon, guided by the guide rolls 27, as a substantially horizontal run into the vertical treatment gap 90V in the airborne web dryer 90, running downwards therein. From the treatment gap 90V the web W is passed further, guided by the guide rolls 27, onto the first drying cylinder 33a and, in a way known in prior art, further through the after-dryer 30.

The more detailed construction of the infrared-airborne web dryer 40 comes out from the attached Figures 2, 2A, 2B, 2C, and 2D. The infrared-airborne web dryer 40 comprises an infrared drying unit 50, through whose treatment gap the web W is passed free of contact, while it is, at the same time, dried by means of infrared radiation R. A component air-technically and structurally integrated with the infrared unit 50 is the airborne web dryer 80, which comprises a box part 81 of the dryer and, fitted in the box part, an upper nozzle box 82A and a lower nozzle box 82B. In the upper nozzle box 82A there are several nozzle units 85a as uniformly spaced H, and correspondingly in the lower nozzle box 82B there are nozzle units 85b as uniformly spaced H, so that a treatment gap 80V is formed, through which the web W to be dried and supported runs while meandering gently and substantially sinusoidally, at the same time as drying and supporting hot air jets are directed at it from both sides.

As is seen from Figures 2 and 3, in the invention the infrared drying unit 50 and the airborne web drying unit 80 are integrated as a novel drying unit both structurally and from the point of view of the drying process, mainly in consideration of the drying-energy-technical matters and of the optimal drying process and draw of the web. This novel dyring-technical and air-technical integration is the essence of the invention.

In the infrared-airborne web dryer 40 in accordance with the invention, the cooling air needed by

the infrared dryer 50 is blown through the nozzles 55A and 55B so as to constitute replacement air for the airborne web drying unit 80 and/or 90. In the invention, the leakage air entering into the airborne web dryer unit 80 can be sealed, and the energy of the hot cooling air coming from the infrared dryer 50 can be utilized efficiently. The combined infrared-airborne web dryer 40 in accordance with the invention permits a strong evaporation energy peak to be applied to the web immediately after the coating process and at the beginning of the drying process (Fig. 4, to be reverted to later).

In the following, with reference to Figures 2, 2A, 2B, 2C, 2D, 3, and 4, the details of the construction and operation of the infrared-airborne web dryer 40 will be described. It is an essential feature of the invention that the infrared dryer unit 50 is placed before the airborne web drying unit 80, in the direction of running W_{in}-W_{out} of the web W to be dried. The infrared drying unit 50 comprises an upper box part 51A and a lower box part 51B. At their front side, these box parts 51A and 51B define a gap part G, into which the web W_{in} is passed. From the gap part G, an air-sealed inlet nozzle and a gap for infrared treatment of the web W start, wherein the web W is supported and stabilized by means of air jets F_A and F_B and wherein it is, at the same time, heated and dried by means of infrared radiation R.

The infrared unit 50 comprises an upper box part 54A and a lower box part 54B. Air pipes 53A and 53B are connected to the said box parts. In the upper box 54A there is a series of infrared radiators 60, above which there is a reflecting face 62 placed inside a heat insulation 61. At the opposite side of the treatment gap, on a heat insulation 64, there is a reflecting face 63, which reflects any infrared radiation R that has passed through the web W back so as to act upon the web W. In connection with the inlet gap G, the

boxes 51A and 54A define an accompanying-air duct 55A, and correspondingly, at the lower side, the boxes 51B and 54B define a lower accompanying-air duct 55B, from which, out of the air passed into the boxes 51A and 51B through the pipes 52A and 52B, accompanying-air blows F_A and F_B are blown, which support and stabilize the web W in the infrared-treatment gap and ventilate the said gap. In the infrared-treatment gap the air jets F_A and F_B are heated, and this heat is recovered by means of the arrangements illustrated in Figures 2A and 3, which will be reverted to later.

From Fig. 2A, which is a section A-A in Fig. 1, it comes out that the air introduced through the duct 104 of the blower 103 (Fig. 3) is blown as flows F_{Ain} through the pipe 52A and 54A into the upper box parts 51A,54A of the infrared unit 50, from which the air flows are directed mainly into the infrared-treatment gap so as to constitute the above accompanying blow F_A. As comes out from Figures 2 and 2A, the inlet flows F_{Bin} from the pipes 52B and 53B connected to the duct 104 are passed into the lower box part 51B of the infrared unit 50 (Fig. 3), which said inlet flows F_{Bin} are directed substantially so as to constitute the above accompanying flow F_B. The flows F_{Ain} and F_{Bin} passed into the inner box parts 54A and 54B surrounding the infrared-treatment gap are guided in the direction of the arrows F_{A2} and F_{B2} so as to cool the parts heated by the infrared radiation, and these cooling flows are at least partly passed into the infrared treatment gap and join the sealing and accompanying flows F_A and F_B. After the infrared-treatment gap, ducts 62A and 62B are opened at the proximity of the web W over the entire width of the web W, the said ducts 62A and 62B communicating with the boxes 106A and 106B. From the said boxes 106A and 106B, pipes 56A and 56B start, which are connected to the pipe 105 seen in Fig. 3. The boxes of the infrared unit 50 and of the airborne unit 80 have an integrated

construction, and between the said units there are partition walls 63A and 63B, which are provided with heat insulation if necessary. Even though above, in connection with Fig. 2, the web is shown as passing in a horizontal plane through the infrared-treatment gap and the immediately following treatment gap 80V of the airborne web drying unit, the run of the web may equally well be slanting or vertical, as is the case in the embodiment shown in Fig. 1. The vertical run starting from the gap G may also be directed from above downwards.

The infrared radiators 60 are divided, in the transverse direction of the web W, into compartments $60_1 \ldots 60_N$, into each of which said compartments it is possible to supply an adjustable electric power through the electric conductor 150 (Fig. 3) so that the transverse profile of the heating effect can be controlled by means of electric systems in themselves known. The profile control system also includes devices (not shown) for the measurement of the transverse moisture profile.

Below the infrared units 60, placed facing the treatment gap, there are windows 60A, through which the infrared radiation R is applied to the web W and penetrates into the web, partly passing through the web W and returning from the reflecting face 63 back so as to act upon the web W.

Figures 2C and 2D show two alternative constructions of the nozzle 85 for the airborne web dryer 80. Fig. 2C shows a float nozzle, which comprises a box part 86A, into which the blow air is passed in the direction of the arrow F_1. The said hot and drying blow air is distributed into the lateral ducts 87a and 87b placed at the sides of the nozzle box 86A, into which said ducts the component flows F_{2a} and F_{2b} of the flow F_1 are directed. At the ends of the said lateral ducts 87a and 87b placed next to the web W, there are nozzle slots 88A and 88B, which blow the jets F_{3a} and F_{3b}, one opposite the other, along the carrying face 89A for the

web W. In the middle of the said carrying face 89, there is a recess S. In the way described above, a pressurized drying area K+ stabilizing the web is formed, out of which area the air is discharged as flows F_{4a} and F_{4b} to the sides of the nozzle box 85, so that a sufficient turbulence and a good heat transfer are formed between the blow-air jets and the web W.

Fig. 2D shows a second, alternative nozzle of the foil type, which comprises a nozzle box 86B, wherein there is one lateral duct 87, whose end placed next to the web W is provided with a nozzle slot 88. The blow air is passed into the nozzle box 86B as a flow F_1, which is divided into the lateral duct 87 as a flow F_2, which is discharged as a jet F_3 along a coanda face 88C placed after the nozzle 88, following the said face 88C within the sector a and being detached from the said carrying face before the plane carrying face 89B, in connection with which a carrying face with negative pressure and a drying gap K- are formed, the air being discharged from the said drying gap K- as a flow F_4 in the direction shown by the arrow into the spaces between the nozzle boxes 85. Fig. 2 shows how the nozzles shown in Figs. 2C and 2D are placed relative each other. In the air-borne web dryer in accordance with the invention, it is also possible to use nozzles different from those shown in Figures 2C and/or 2D.

Figures 4A and 4B show a graphic comparison of the evaporating capacities (kg/m^{2}h) of the prior-art dryer shown in Fig. A and the dryer in accordance with the present invention shown in Fig. 1.

According to Fig. 4A, in a prior-art dryer of the sort shown in Fig. A, which consists of two separate infrared dryers and a leading cylinder placed between them, the evaporation within the area of the first infrared unit, i.e. within the time period t_1-t_2, rises to the level of about 40 kg/m^{2}h, whereinafter, on the open draw following after the first infrared

unit, the evaporation is lowered, within the time period t_2-t_3, to the level of about 25 kg/m^{2}h. Hereupon, within the area of the leading cylinder (23A), the evaporation remains at a low level and rises to a level of about 25 kg/m^{2}h at the time t_4, where the open draw after the leading cylinder (23A) starts. The time period t_5-t_6 represents the second infrared unit, which is located in place of the airborne web dryer 26 shown in Fig. A. Hereinafter there follows an open draw within the time period t_6-t_7, whereat the evaporation is lowered substantially exponentially.

When the evaporating capacity of the infrared-airborne web dryer in accordance with the invention, shown in Fig. 4B, is compared with that illustrated in Fig. 4A, the following can be noticed. Within the time period t_1-t_2 the web W runs through the infrared-treatment gap of the infrared-treatment unit 50 in accordance with the invention. The length of the said infrared-treatment gap is, e.g., about 400 mm. Within the said time period t_1-t_2 the evaporation capacity rises from zero to the level of about 40 kg/m^{2}h, whereinafter, within the time period t_2-t_3, there follows the treatment gap 80V of the airborne unit 80 of the dryer in accordance with the invention. From the time t_2 the evaporation rises very steeply so that an evaporation peak Hp_1 is formed, whose maximum is at a level of about 180 kg/m^{2}h. After the maximum point of the said evaporation peak, the evaporation capacity becomes lower until the time t_3, which represents the final point of the treatment gap 80V, to a level of about 70 kg/m^{2}h. The above evaporation peak Hp_1 is highly characteristic of the present invention and is accomplished expressly thereby that in the infrared-treatment gap of the unit 50 evaporating energy can be fed into the structure of the web W, which said energy is "discharged" as evaporating capacity in the airborne web treatment gap 80V owing to the efficient ventilation provided therein. In Fig. 4B the

width of the evaporation peak Hp_1 is denoted with t_0. The width t_0 of the evaporation peak is, as a rule, within the range of t_0 = 0.1 to 0.5 s, preferably t_0 = 0.15 to 0.3. In Fig. 4B, $t_0 \approx 0.2$ s when the web W speed v_0 = 10 m/s. The length of the air-treatment gap 80V, which represents the said time period t_2-t_3, is about 2 m. After the said evaporation peak t_0 the evaporation capacity is lowered within the time period t_3-t_4, which represents the open draw of the web W between the infrared-airborne unit 40 and the following conventional airborne unit 90 in Fig. 1. After this, in the treatment gap 90V of the airborne web drying unit 90, which is represented by the time period t_4-t_5 in Fig. 4B, the drying capacity rises substantially exponentially to the level of about 80 kg/m^{2}h, whereupon it is suddenly lowered to the level of about 20 kg/m^{2}h, where the evaporation takes place within an open draw before the multi-cylinder dryer, which is represented by the time period t_5-t_6 in Fig. 4B.

As is seen from Fig. 2, the treatment gap in the infrared unit 50 and the treatment gap 80V in the airborne web drying unit 80 are in the same plane, so that the web W makes no bends when it runs through the combined infrared-airborne dryer 40. Owing to the sealing and accompanying blows F_A and F_B, the web W can be made, even initially, to run in a stable way into and through the infrared-treatment gap, and the stabilized run of the web W continues in the treatment gap 80V of the airborne web drying unit 80. It is partly also owing to this that quite high web speeds can be used, which may be even considerably higher than 1000 m/min.

In this way it is possible to make water to evaporate rapidly from the face of the web W coating, and in the airborne web drying unit 80 following immediately after the infrared unit 50, the location of the solid area in the coating base can be adjusted favourably so that it becomes placed, e.g., in the free

space after the airborne web drying unit 80. In this way, an occurrence of the mottling phenomenon can be prevented. A strong evaporation peak H_{p1} immediately after the coating process also reduces the occurrence of fibre roughening.

Fig. 3 shows an exemplifying embodiment of an air system applicable in connection with the method and device of the present invention. The drying air is passed through the duct 100 into a filter 101 and from there further into the intake duct 102 of the blower 103. The pressure duct 104 of the blower 103 communicates via the pipes 52A,53A and 52B,53B with the boxes 51A,54A and 51B,54B of the infrared unit, from which flows are branched to as to constitute the accompanying blows F_A and F_B discharged from the nozzles 55A and 55B and shown in Fig. 2. The air cooling the infrared unit 50 is recovered so as to constitute replacement air for the airborne web drying unit 80 and/or 90.

According to Fig. 3, an intake duct 105 starts from the chambers 106A and 106B, through which said duct 105 air is passed to the suction side of the blower 107 of the airborne web drying unit 80 so as to constitute burning air for the burner 116. The regulator of the said intake side is denoted with the reference numeral 120. The duct at the pressure side of the blower 107 is passed to a gas burner 116, to which the duct at the pressure side of the second blower 113 is also passed. In connection with the suction duct 115 of the said blower 113, there is a regulator 121. The duct 110 at the outlet side of the gas burner 116 passes the hot and dry air into the nozzle boxes 82A and 82B of the airborne web drying unit 80. The air is taken from the nozzle boxes 82A and 82B through the duct 111 into the duct 115. Between the ducts 110 and 111, there is a by-passing duct 112, which is provided with regulators 114. The ducts 115 and 111 pass to the exhaust duct 122, and from there further to the duct 131 of the suction side of the

exhaust blower 132, in which said duct 131 there is a regulator 133. Between the ducts 105 and 112, there is a blower 125. The cooling-air duct 105 of the infrared unit 50 is also passed to the suction duct of the burning-air blower 140 of a separate infrared unit 90 as well as to the exhaust duct 130 of a separate airborne web drying unit 90. In the other respects, the air arrangement of the separate airborne web drying unit 90 is similar to the air arrangement described above in respect of the airborne web drying unit 80.

In the embodiment shown in Figures 1 and 3, the electric power P_s passed to the infrared unit 50 through the conductor 150 is, e.g., of an order of P_s = 740 kW, and the heating power P_1 of the blowing air for the airborne part 80 of the infrared-airborne dryer 40 (gas burner 116) is of an order of P_1 = 300 kW. The heating power of the blowing air of a conventional airborne web dryer 90 is, e.g., of an order of P_2= 1300 kW.

In the applications in accordance with the invention, the electric power of the infrared unit 50 is preferably $P_s = (2...3) \times P_1$. If one thinks of the overall power of the dryers 40 and 90 in a coating station 20, it is, in the case shown in Figs. 1 and 3, $P_{tot} = P_s + P_1 + P_2 = 740 + 300 + 1300 = 2340$ kW. Preferably, in the invention, the electric power P_s of the infrared unit 50 is about 25 to 40 % of the overall power P_{tot}, preferably 30 to 35 %. From the above it can be noticed that in the invention it is possible to operate with a relatively low proportion of more expensive electric power P, and the air-heating energies P_1 and P_2 can be taken advantageously from natural gas, if it is available, or from some other corresponding energy that is less expensive than electric energy. Thus, owing to the invention, the favourable effects of infrared drying can be obtained with a relatively low proportion of electric energy.

In the following, the patent claims will be given, whereat the various details of the invention

may show variation within the scope of the inventive idea defined in the claims and differ from the details given above for the sake of example only.

WHAT IS CLAIMED IS:

1. Method for contact-free drying of a paper or board web (W) or of any other, corresponding continuous web (W), in which method both infrared radiation (R) and drying air jets are used for drying, my means of which said air jets the web (W) running through the dryer (40) is, at the same time, carried free of contact, preferably from two sides, and in which said method, after the infrared drying gap, the web (W) is substantially immediately passed into an airborne web-drying gap (80V), wherein the web (W) is supported and dried by means of air jets, characterized in

- that in the method the moving web (W) is first passed into an infrared drying gap, in which a drying energy pulse of relatively short duration is directed at the web (W), the power of the said energy pulse being substantially higher than the average drying power of the dryer per unit of area, and

- that air (F_{Ain},F_{Bin}) is brought into the infrared unit (50), which said air, having been heated in the infrared unit (50), is passed as replacement air and/or drying air for the airborne web-drying unit (80;90) or units (80,90) placed after the infrared unit.

2. Method as claimed in claim 1, characterized in that the air flows (F_{Ain},F_{Bin}) to be passed into the said infrared unit (F) are passed in connection with the inlet gap (G) of the web (W) to both sides of the web (W) so as to make accompanying and sealing jets (F_A,F_B) out of nozzles (55A,55B), which said jets (F_A,F_B) are blown into the infrared-treatment gap so as to support the web (W) and to cool the apparatuses placed in its connection.

3. Method as claimed in claim 1 or 2, characterized in that after the combined infrared and airborne web drying unit (40), the web (W) is dried and supported free of contact in a conventional

airborne web drying unit (90).

4. Method as claimed in any of the claims 1 to 4, c h a r a c t e r i z e d in that the replacement air to be passed into the airborne web drying unit (80) or units (80,90) is taken exclusively from the cooling air fed into (F_{Ain},F_{Bin}) the infrared unit (50), which said cooling air is additionally used for sealing the inlet gap (G), for supporting the web (W), and for accompanying the web (W) in the infrared-treatment gap right from its inlet gap (G).

5. Method as claimed in any of the claims 1 to 4, c h a r a c t e r i z e d in that the electric power (P_s) applied to the web in a combined infrared-airborne web drying unit (40) is about 2...3 times as high as the power (P_1) used in the airborne web drying unit (80) for heating its drying air (P_s = (2...3) x P_1).

6. Method as claimed in any of the claims 1 to 5, c h a r a c t e r i z e d in that in the method the electric power (P_s) that produces the infrared radiation (R) applied to the web (W) is about 25 to 40 %, preferably about 30 to 35 % of the overall drying power (P_{tot}) applied to the web (W) in the dryer.

7. Method as claimed in any of the claims 1 to 6, c h a r a c t e r i z e d in that in the method a gas is used for heating the drying air in the airborne web drying unit (80) or units (80,90).

8. Drying device intended for carrying out the method as claimed in any of the claims 1 to 7, which said drying device comprises an infrared drying unit (50) and an airborne web-drying unit (80) or airborne web-drying units (80,90), which said infrared drying unit (50) comprises a series (60_1-60_N) of infrared radiators (60) and an infrared-treatment gap fitted in its connection, through which said gap the web (W) to be dried can be passed, and which said airborne web-drying unit (80) or units (80,90) comprise a box portion (81) inside of which a nozzle box or boxes (82A,82B) are fitted, in

connection with which there are nozzle parts (85A,85B), through which drying and supporting air jets ($F_3;F_{3a}$, F_{3b}) are applied to the web (W) to be dried, which said device comprises an infrared drying unit (50) and an airborne web-drying unit (80), which are integrated with each other both structurally and functionally, and which said infrared unit (50) is placed, in the direction of running ($W_{in}-W_{out}$) of the web (W) to be dried, immediately before the airborne web-drying unit (80), c h a r a c t e r i z e d in that the infrared drying unit (10) comprises air and nozzle devices (52A,53A,55A, 52B,53B,55B), through which air flows can be passed into the treatment gap of the infrared unit (50) and/or into connection with the heated parts of the infrared unit, which said air flows are passed for replacement and/or drying air for the subsequent airborne web-drying unit (80;90) or units (80,90).

9. Drying device as claimed in claim 8, c h a r a c t e r i z e d in that between the infrared unit (50) and the airborne web-drying unit (80) following substantially immediately after the infrared unit, air ducts (62A,62B) are fitted, whose mouths placed facing each other are opened at the proximity of the web (W) running past the said mouths, and that the said ducts (62A,62B) pass to exhaust air ducts (56A,56B), which pass the air heated in the infrared unit to the airborne web drying unit or units (80,90) so as to constitute burning air for their gas burner (116) or burners.

10. Device as claimed in claim 9, c h a r - a c t e r i z e d in that the infrared unit (50) comprises an inlet gap (G), into which the web (W) to be treated can be guided, and that immediately at both sides of the said inlet gap (G) there are foil-type nozzles (55A,55B), which extend across the entire width of the web (W) and through which blows (F_A,F_B) can be blown from both sides of the web (W), which blows, at the same time, cool the parts placed in connection with the

infrared-treatment gap and heated by the infrared radiation.

11. Device as claimed in claim 9 or 10, c h a r a c t e r i z e d in that the infrared radiation unit (60) is divided in compartments ($60_1 \ldots 60_N$), into each of which an adjustable electric power can be passed for adjustment of the distribution of the drying capacity of the device in the transverse direction in view of controlling the moisture profile of the web (W).

12. Device as claimed in any of the claims 9 to 11, c h a r a c t e r i z e d in that the treatment gap of the infrared unit (50) immediately preceding the airborne web-drying unit (80) is placed in the same plane as the treatment and supporting gap (80V) in the airborne web-drying unit (80).

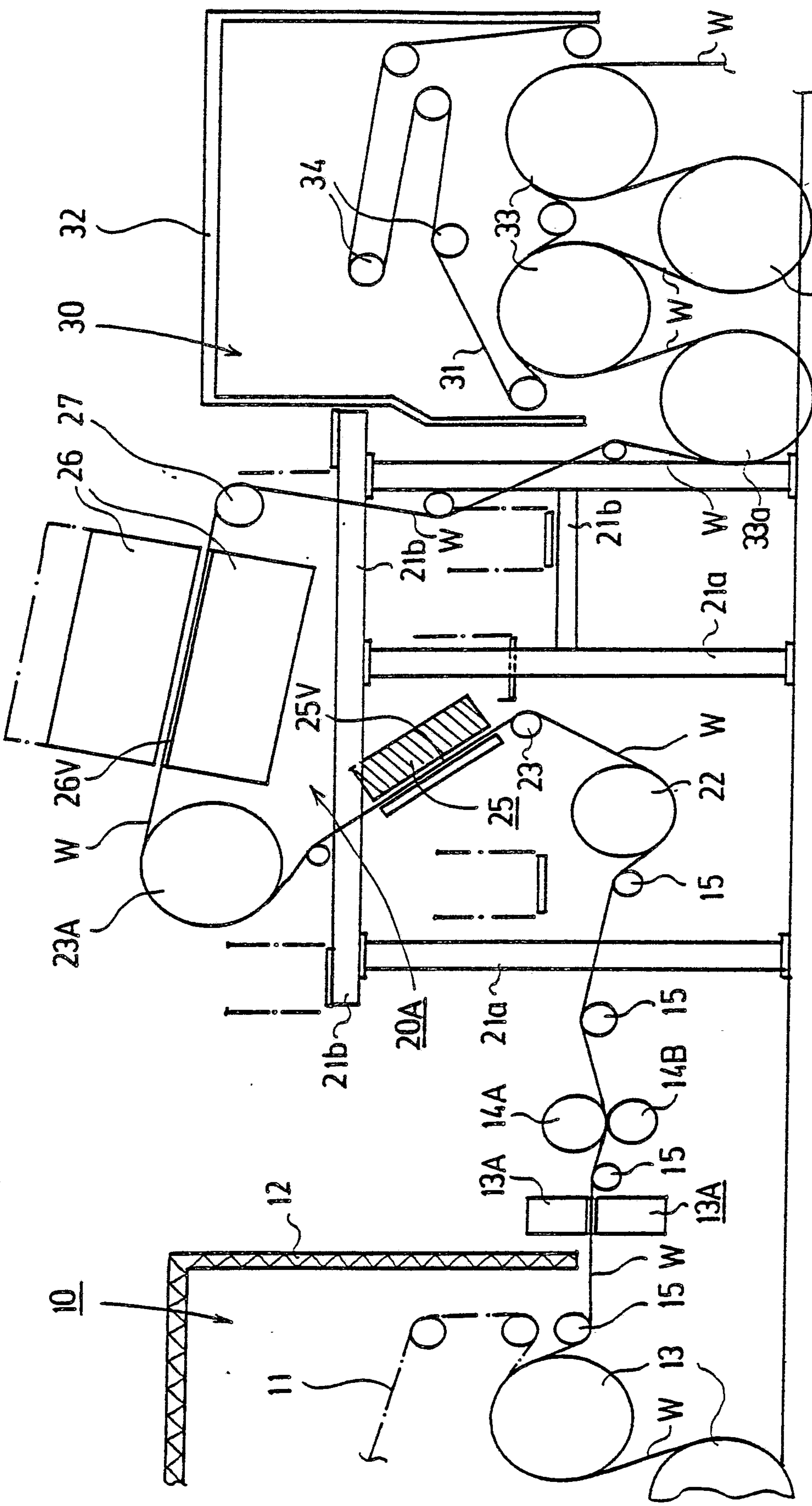
10
11
12
13
13A
14A
14B
15
W
20A
21a
21b
22
23
23A
25
25V
26
26V
27
30
31
32
33
33a
34

FIG. A

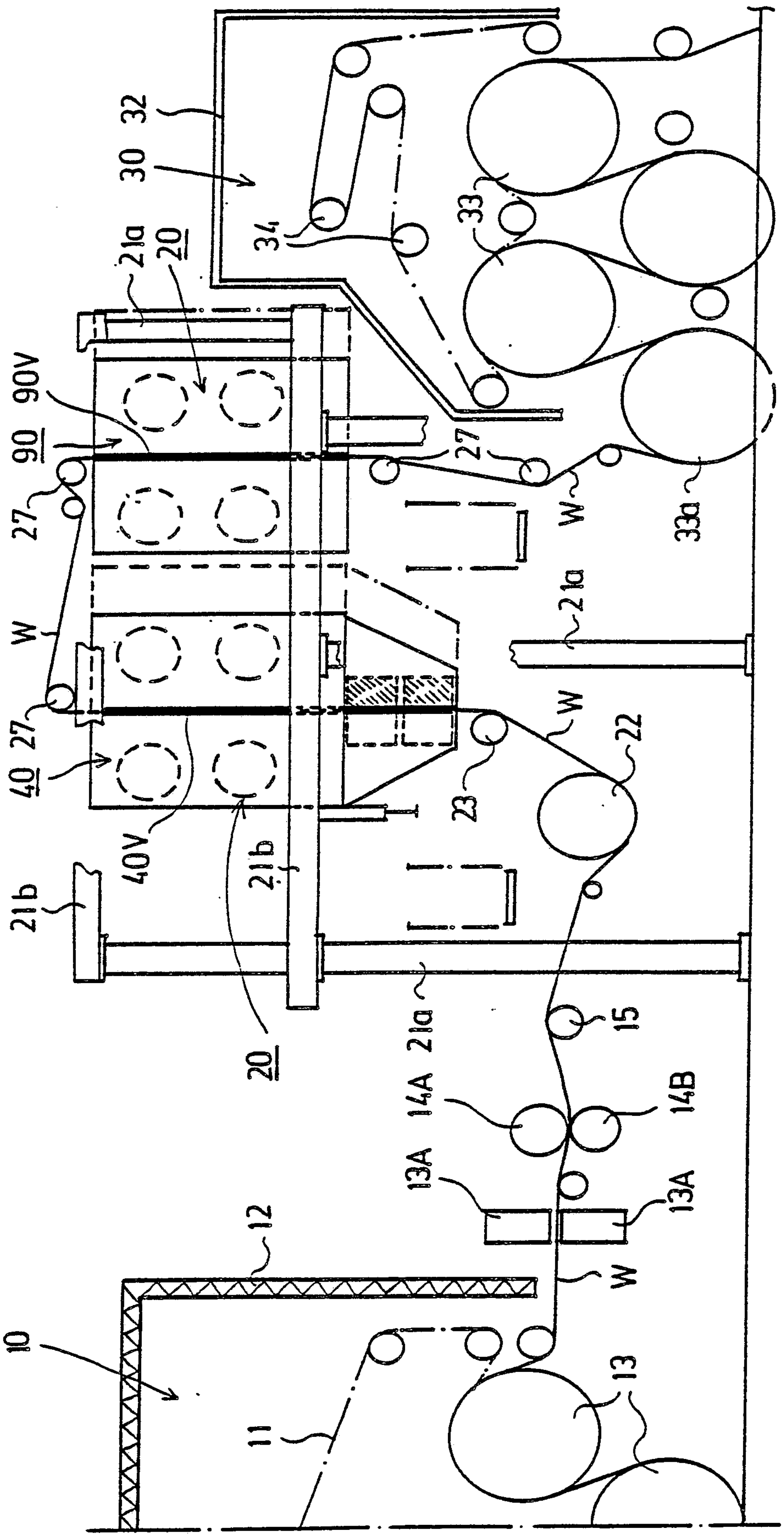
10
11
12
13
13A
14A
14B
15
20
21a
21b
22
23
27
30
32
33
33a
34
40
40V
90
90V
W

FIG.1

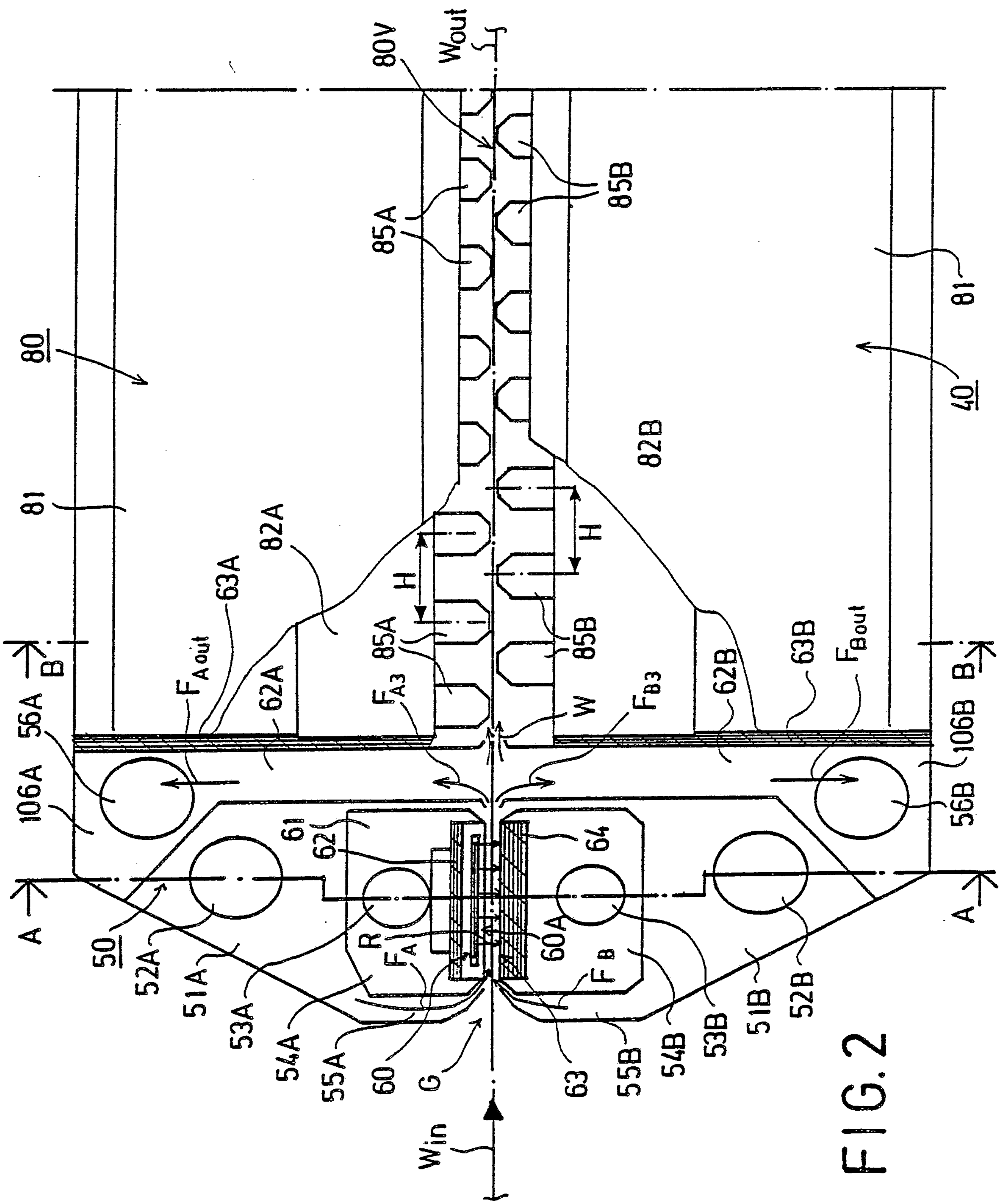
80
81
80V
W out
85A
85B
82A
82B
81
40
H
H
B
B
63A
F A out
62A
56A
106A
F A3
W
F B3
62B
63B
F B out
106B
56B
61
62
64
60A
R
F A
F B
A
A
50
52A
51A
53A
54A
55A
60
G
63
55B
54B
53B
51B
52B
W in

FIG. 2

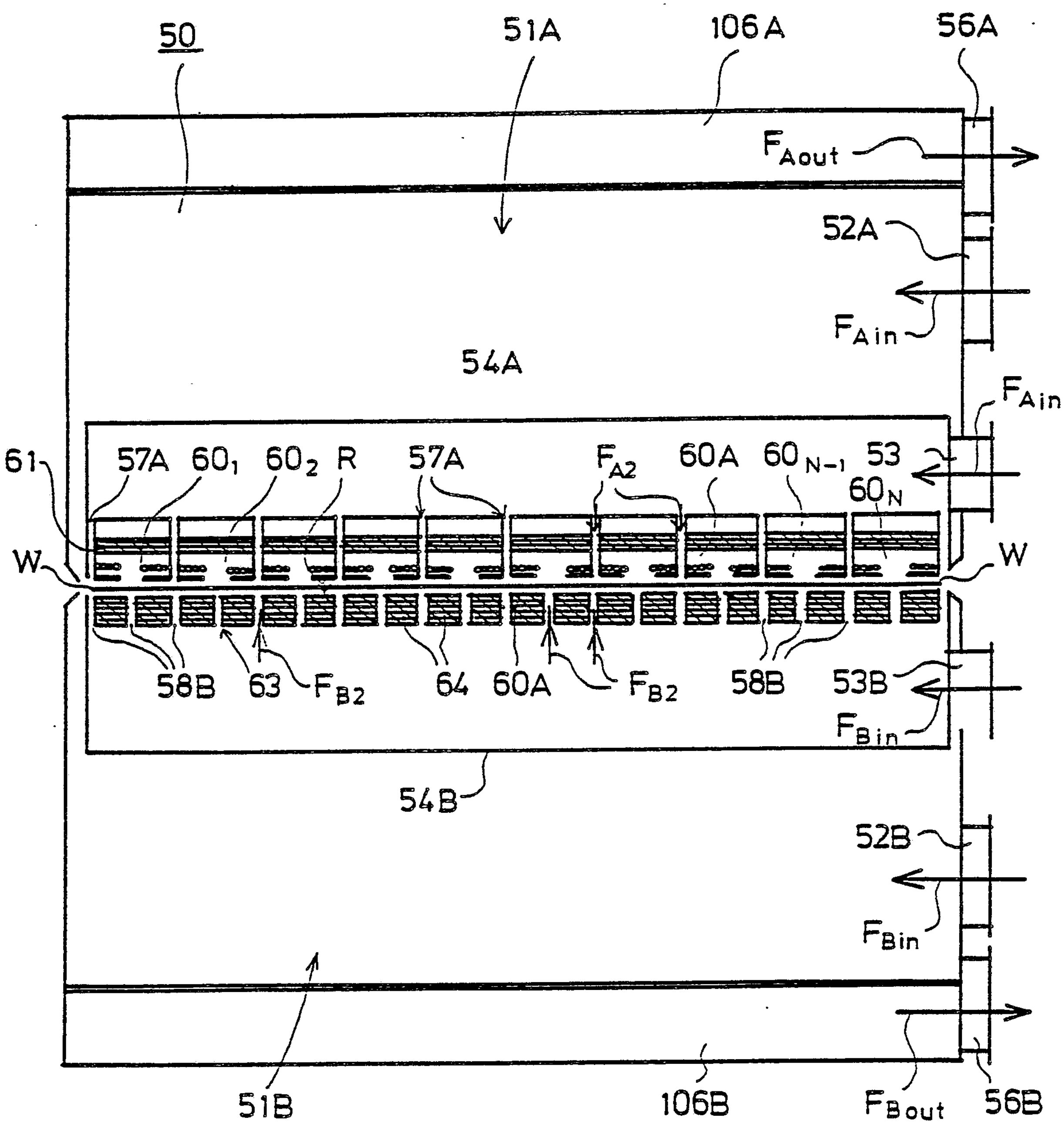
50
51A
106A
56A
F_{Aout}
52A
F_{Ain}
54A
F_{Ain}
61
57A
60_1
60_2
R
57A
F_{A2}
60A
60_{N-1}
53
60_N
W
W
58B
63
F_{B2}
64
60A
F_{B2}
58B
53B
F_{Bin}
54B
52B
F_{Bin}
51B
106B
F_{Bout}
56B

FIG. 2A

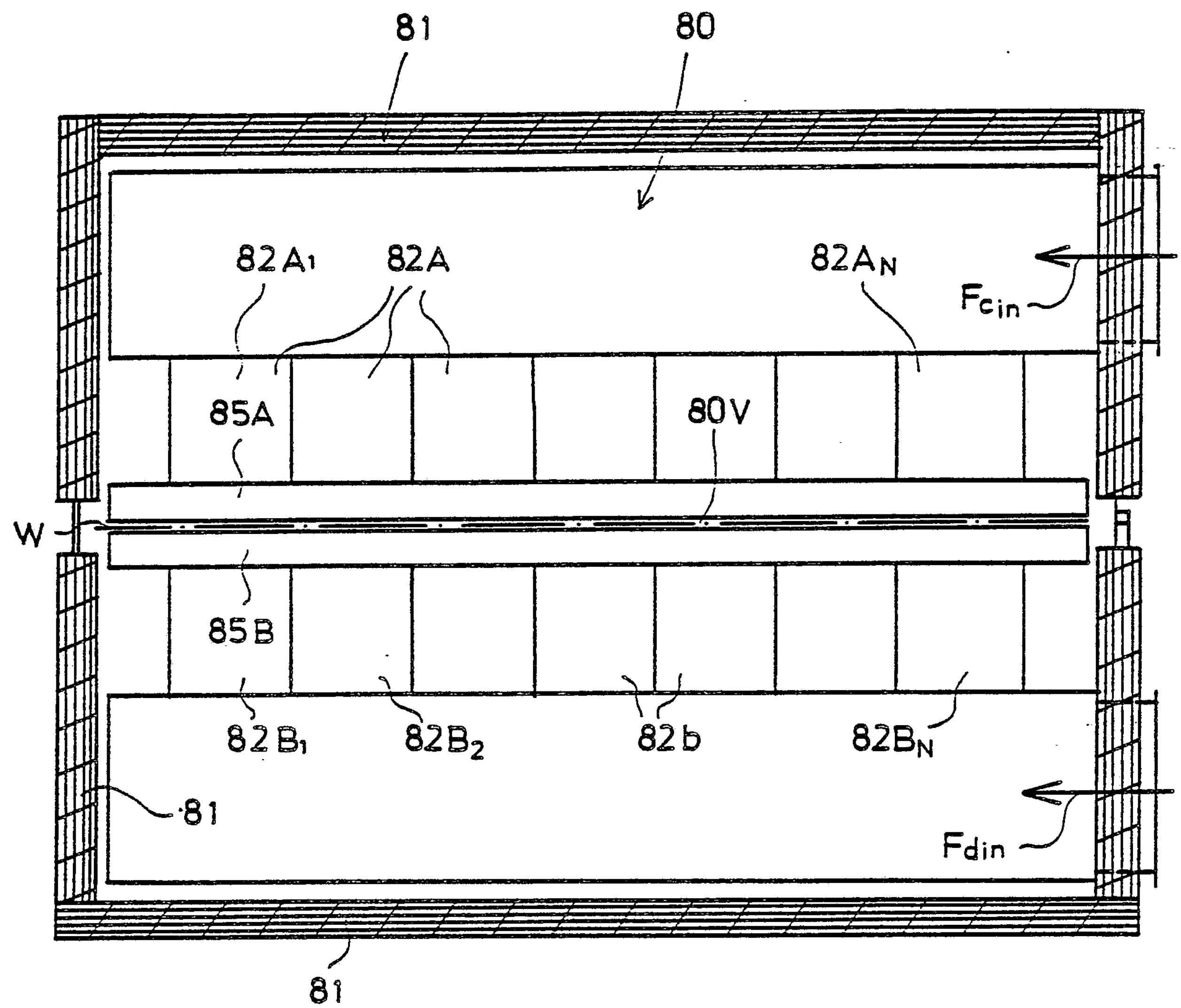
81
80
82A1
82A
82AN
Fcin
85A
80V
W
85B
82B1
82B2
82b
82BN
81
Fdin
81

FIG. 2B

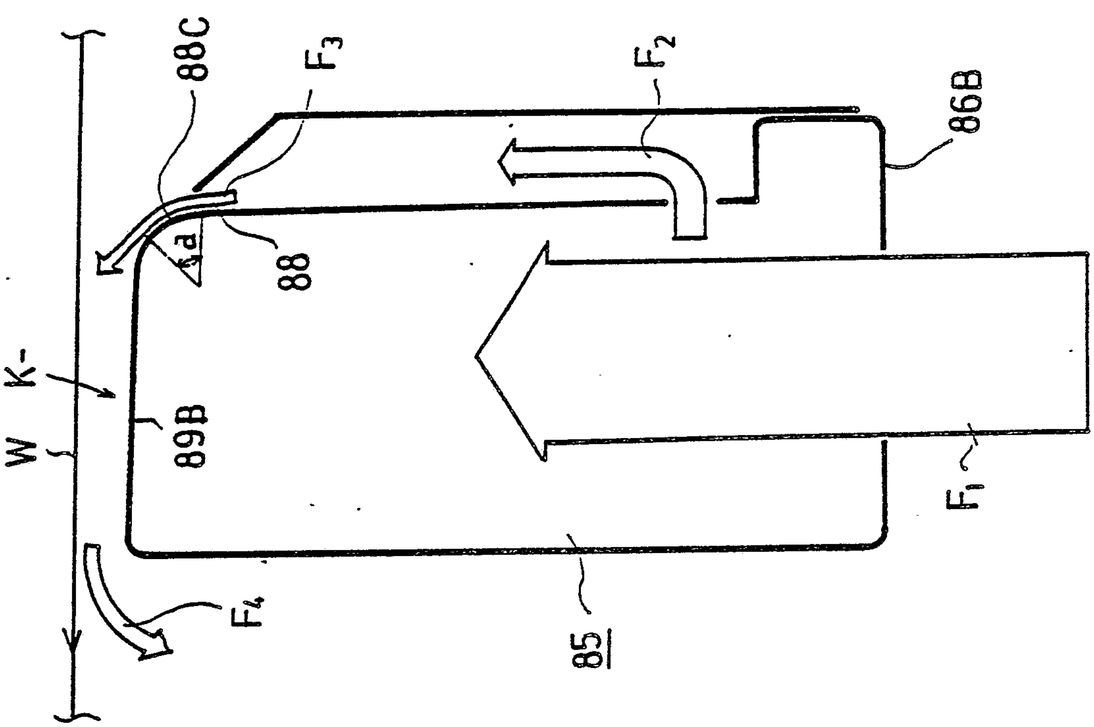
W
K-
88C
F3
F2
86B
88
89B
F1
F4
85

FIG. 2D

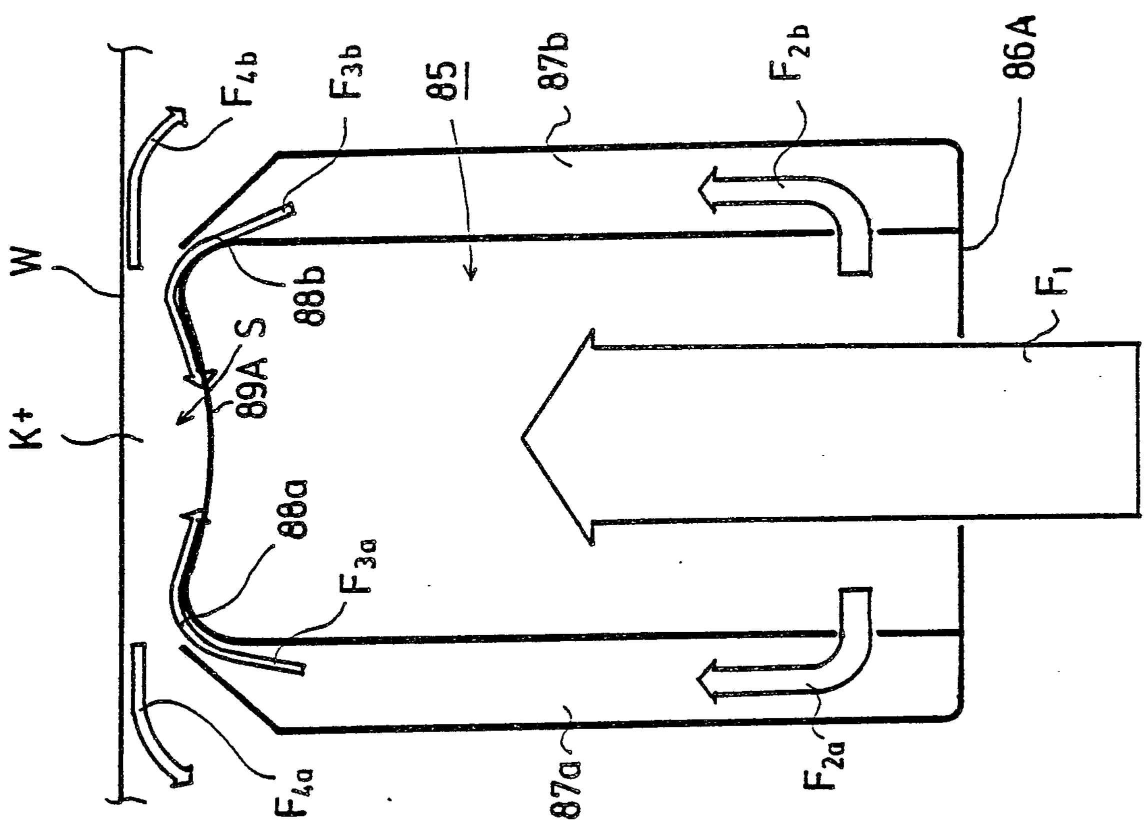
K+
W
F4b
F3b
85
87b
F2b
86A
88b
S
89A
F1
88a
F3a
F4a
87a
F2a

FIG. 2C

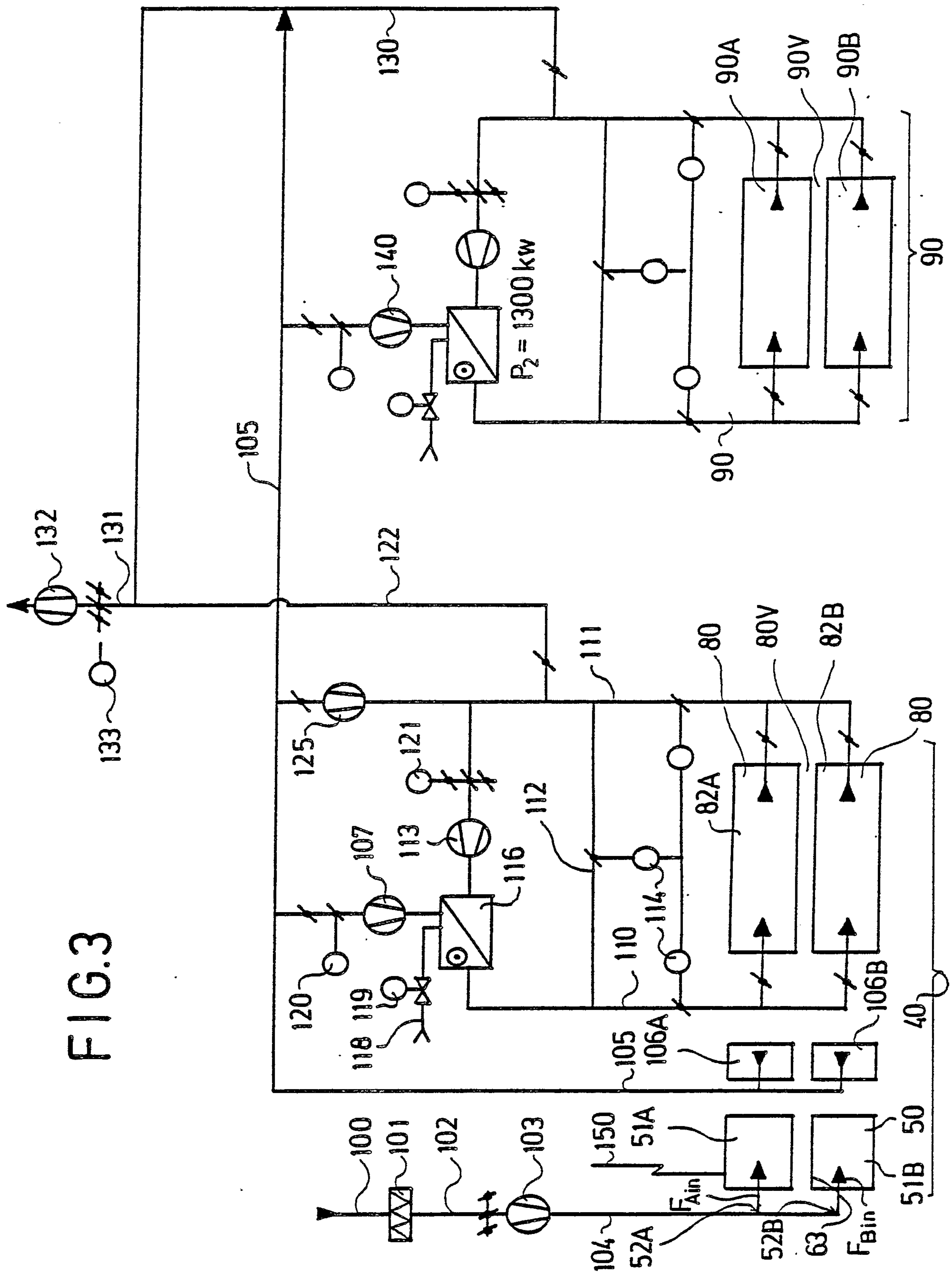
130
90A
90V
90B
140
$P_2 = 1300$ kw
90
105
90
132
131
122
111
80
80V
82B
133
125
121
80
107
113
112
82A
116
114
110
120
119
118
105
106A
106B
40
100
101
102
103
150
51A
50
51B
104
52A
52B
63
F_{Ain}
F_{Bin}

FIG.3

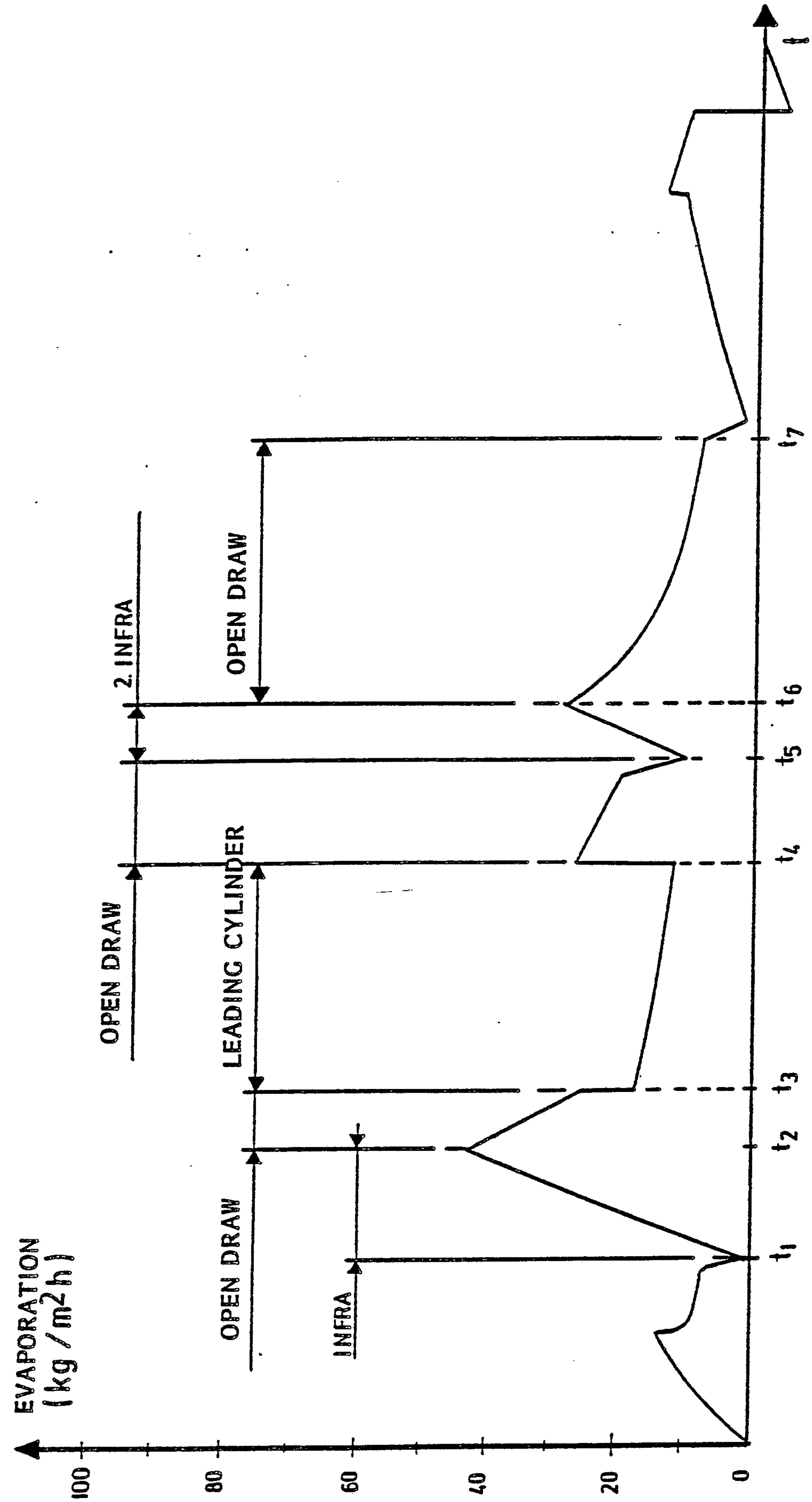
EVAPORATION
(kg/m2h)
100
80
60
40
20
0
INFRA
OPEN DRAW
LEADING CYLINDER
OPEN DRAW
2. INFRA
OPEN DRAW
t1
t2
t3
t4
t5
t6
t7
t

FIG. 4A

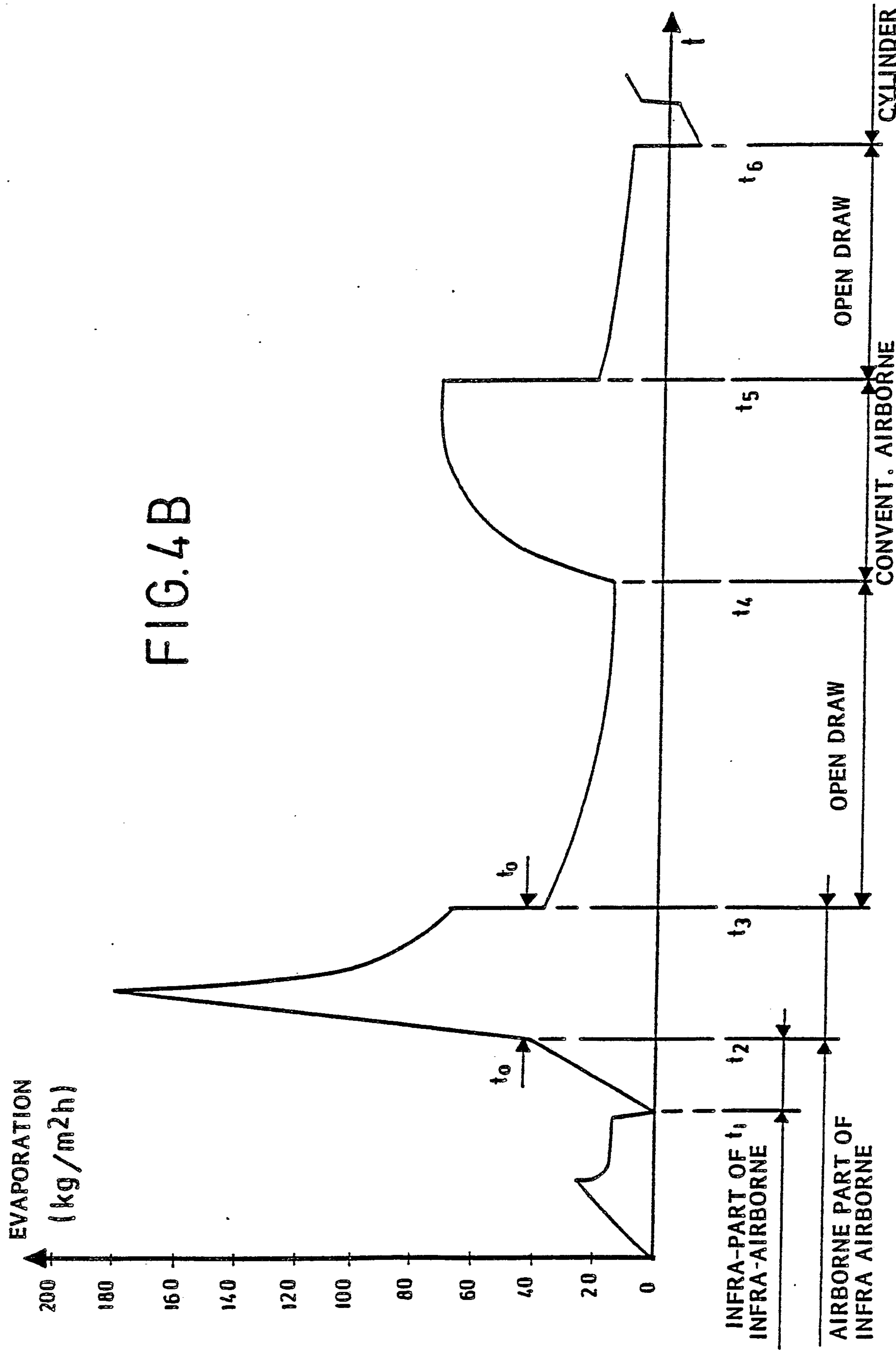
EVAPORATION
(kg/m2h)
200
180
160
140
120
100
80
60
40
20
0
t
t0
t1
t2
t3
t4
t5
t6
INFRA-PART OF INFRA-AIRBORNE
AIRBORNE PART OF INFRA AIRBORNE
OPEN DRAW
CONVENT. AIRBORNE
OPEN DRAW
CYLINDER GROUP

FIG.4B

INTERNATIONAL SEARCH REPORT

International Application No PCT/FI87/00159

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

D 21 F 5/00, F 26 B 3/30, 13/10

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC 4	D 21 F 5/00,/16,/20; F 26 B 3/30, 13/10,/20, 23/04,/06
Nat cl	82a:34
US Cl	34:4, 41, 68

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	GB, A, 1 530 823 (BAYER AKTINGESELLSCHAFT) 1 November 1978	
A	US, A, 3 639 207 (GENZ ET AL) 1 February 1972	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1988-06-21	1988 -07- 0 1
International Searching Authority	**Signature of Authorized Officer**
Swedish Patent Office	Björn Salén Björn Salén